

# EPICYCLIC GEAR TRAIN INTEGRAL SUN GEAR COUPLING DESIGN

## BACKGROUND OF THE INVENTION

This invention relates to planetary gear trains. More particularly, the invention relates to a coupling system for flexibly connecting a sun gear to a rotating shaft so that the reliability and durability of the gear system components are improved. The invention is useful in aircraft engines where reliability, durability and simplicity are highly desirable.

Planetary gear trains are mechanical structures for reducing or increasing the rotational speed between two rotating shafts. The compactness of planetary gear trains makes them appealing for use in aircraft engines where space is at a premium.

The forces and torque transferred through a planetary gear train place tremendous stresses on the gear train components, making them susceptible to breakage and wear, even under ideal conditions. In practice, conditions are often less than ideal and place additional stresses on the gear components. For example, the longitudinal axes of a sun gear, a planet carrier, and a ring gear are ideally coaxial with the longitudinal axis of an external shaft that rotates the sun gear. Perfect or ideal coaxial alignment, however, is rare due to numerous factors including imbalances in rotating hardware, manufacturing imperfections, and transient flexure of shafts and support frames due to aircraft maneuvers. The resulting parallel and angular misalignments impose moments and forces on the gear teeth, the bearings which support the planet gears in their carrier, and the carrier itself. The imposed forces and moments accelerate gear component wear and increase the likelihood of component failure in service. Thus, accelerated component wear necessitates frequent inspections and part replacements which can render the engine and aircraft uneconomical to operate.

The risk of component breakage can be reduced by making the gear train components larger and therefore stronger. Increased size may also reduce wear by distributing the transmitted forces over correspondingly larger surfaces. However, increased size offsets the compactness that makes planetary gear trains appealing for use in aircraft engines, and the corresponding weight increase is similarly undesirable. The use of high strength materials and wear resistant coatings can also be beneficial, but escalates the cost of the gear train and therefore reduces its desirability.

Stresses due to misalignments can also be reduced by the use of flexible couplings to connect the gear train to external devices such as rotating shafts or nonrotating supports. For example, a flexible coupling connecting a sun gear to a drive shaft flexes so that the sun gear remains near its ideal orientation with respect to the mating planet gears, even though the axis of the shaft is oblique or displaced with respect to a perfectly aligned orientation. Many prior art couplings, however, contain multiple parts which require lubrication and are themselves susceptible to wear. Prior art couplings may also lack adequate rigidity and strength, with respect to torsion about a longitudinal axis, to be useful in high torque applications. Misalignment can also be accommodated by a splined connection. However the motion that occurs between the contacting spline teeth in a splined connection creates friction which is highly variable and causes the flexibility of such a connection to also be variable.

In view of these shortcomings, a simple, reliable, coupling system for connecting components of a planetary gear train to external devices while accommodating misalignment there between is sought.

## BRIEF SUMMARY OF THE INVENTION

The invention is a planetary gear train driven by a shaft and containing a sun gear, a ring gear secured to a ring gear housing, a plurality of planet gears rotatably mounted in a planet carrier and meshing with the sun gear and the ring gear, and a coupling system. The coupling system comprises a sun gear coupling connecting the sun gear to the shaft, the sun gear coupling having at least one undulant flexible section joined to an inflexible spindle for accommodating misalignment between the sun gear and the shaft, wherein the undulant flexible section contains two generally parallel interior walls joined by an outer edge member.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic cross-sectional side elevation view of a turbine engine containing a planetary gear train.

FIG. 2 is a cross-sectional elevation view of a coupling system for the planetary gear system of the present invention.

FIG. 3 is a cross-sectional elevation view of an undulant flexible section of the present invention.

## DETAILED DESCRIPTION

FIG. 1 shows a typical turbine engine 10 known in the art, which includes as its principal components one or more compressors 12, 14, one or more turbines 16, 18 for powering compressors 12, 14, combustion chamber 20, fan 22, primary exhaust 24 and fan exhaust nozzle 26. A power train such as shafts 28, 30 extends from each turbine 16, 18 to drive the corresponding compressor 12, 14. The rotary motion of one of compressors 12, 14 is conveyed to fan 22 by way of planetary gear train 32. Planetary gear train 32 reduces the rotational speed of a compressor to a speed more suitable for the efficient operation of fan 22. The principal engine components are ideally concentric with central longitudinal axis 34.

FIG. 2 is a cross-sectional elevation view of an integral coupling system 40 for planetary gear system 32 of FIG. 1, and its relationship to engine 10. Integral coupling system 40 comprises inflexible spindle 42 and at least one undulant flexible section 44 which rotate about central longitudinal axis 34.

Also illustrated are compressor drive shaft 28, planet gear 46, ring gear 48, ring gear housing 50, ring gear coupling 52, and integral sun gear 56. The forward end of compressor drive shaft 28 is joined by splines 54 to the aft end of integral coupling system 40. Integral sun gear 56 engages planet gear 46 through mesh 58. Rotary motion of drive shaft 28 is thus transferred to sun gear 56, which meshes with multiple planet gears 46. Each planet gear 46 is rotatably mounted in planet carrier 62 by journal pin 64 or other suitable bearing so that the rotary motion of integral sun gear 56 urges each planet gear 46 to rotate about longitudinal axis 66. Each planet gear 46 also meshes with ring gear 48 through mesh 60. The ring gear 48 is mounted in ring gear housing 52.

In one embodiment, ring gear coupling 52 joins ring gear housing 50 to a mechanical ground to prevent rotating of the ring gear. Since planet gears 46 mesh with both a nonrotating ring gear 48 and rotating integral sun gear 56, planet gears 46 not only rotate about axes 66 but also orbit integral sun gear 56 causing planet carrier 62 to rotate about axis 34. This is commonly referred to as a planetary gear system. Planet carrier 62 motion is conveyed to fan 22 (of FIG. 1) by any suitable means, not illustrated.

In an alternate embodiment, the ring gear 48 is allowed to rotate, while the planet gears 46 remain in a set position and only rotate about their respective individual central axes. The rotating of the integral sun gear 56 about the planet gears 46